*Jordan Journal of Agricultural Sciences,* Volume **13**, No. **2** 2017

# Growth, Antioxidant Enzymes Activities and Photosynthetic Pigments of Two Rice (*Oryza sativa* L.) Cultivars as Influenced by Application of Gibberellic Acid and Sodium Arsenate

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## ABSTRACT

The effects of gibberellic acid ($GA_3$) and sodium arsenate on enzymatic antioxidants activities (superoxide dismutase**,** guiacol peroxidase and catalase), soluble proteins content, growth andphotosynthetic pigments (chl*a*, chl*b*, total chl. and carotenoids) of 'Tarom' and 'Shiroudi' rice were investigated. Thirty-days-old seedlings were treated withdifferent concentrations of sodium arsenate (0, 50 and 100 µM) and $GA_3$ (0 and 10 µM) for two weeks. The results showed that sodium arsenate increased the activities of the enzymatic antioxidants and protein content significantly and reduced the growth parameters, chl*a*, chl*b*, and carotenoids contents in both cultivars of rice. Meanwhile, $GA_3$ increased the activities of the enzymatic antioxidants, protein content, growth parameters, chl*a*, chl*b*, and carotenoids contents significantly in both cultivars of rice treated with sodium arsenate. In general, the results of this study showed that $GA_3$increased theresistance of the two examinedricecultivars treated withsodium arsenate.

**Keywords**: Rice, enzymatic antioxidants, gibberellic acid, photosynthetic pigments, sodium arsenate, soluble proteins.

**Abbreviations**: GA3 (gibberellic acid), CAT (catalase), POX (peroxidase), SOD (superoxide dismutase)..

## INTRODUCTION

Arsenic is spread out broadly by soil materials, air and human activities in environment (Singh *et al.*, 2009). This heavy metal is presented in rock, soil, water and air in organic and inorganic forms (Rintala*et al.*, 2014). High content of arsenic in some farm soils is due to industrial and agricultural activities decline soil fertility (Miteva*et al.*, 2005). Water pollution containing arsenic has been worrying in many countries including Argentina, Australia, Bangladesh, Chile, China, Hungary, India, Mexico, Peru, Thailand and USA (Chan *et al.*, 2013). However, in anaerobic soils, arsenate (AsV) is the constant form and in reducing condition, arsenite (AsIII) is the dominant species that both are highly toxic for plants. Arsenate is a phosphate analog and it can compete with phosphate in the cytoplasm as a replacement of phosphate in ATP declining energy flows in cells. Arsenic is extremely toxic in plants because, it reacts with sulfhydryl groups in enzymes, their cofactors and proteins. High arsenic concentrations change the activity of several enzymes dealing in metabolism of plants (Singh *et al.*, 2009).

Arsenic transport is depended on pH, arsenic species, redox conditions, inorganic and organic forms of arsenic (Polizzotto*et al.*, 2013). Moreover, plants have several mechanisms against arsenic stress including high affinity phosphate/ arsenate transport system, compartmentalization, reduction and translocation of

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Received on 3/4/2016 and Accepted for Publication on 11/7/2016.

arsenic. Also, phytohormones can induce resistance mechanisms that may provide a strategy to raise the tolerance. GA inhibits the effects of abiotic stress and decreasethe accumulation of heavy metals in plant (such as broad bean), and increases antioxidant activities scavenging reactive oxygen species (ROS) produced in plants under stress conditions (Zhu*et al.*, 2012).

It has been found that gibberellin has a positive effect on plant growth and development (Tuna *et al.*, 2008; Bartoli*et al.*, 2013). Regarding the effect of sodium arsenate on the growth and activity of oxidizing enzymes, Swarnakar (2014) reported that pretreatment with $GA_3$ increased the resistance of mungbean seedlings against As stress. Also, Ghosh *et al.* (2015) found that gibberellic acid was able to dominate the toxic effects of sodium chloride stress in mungbean (*Vignaradiata* L. Wilczek). The current study aimed to investigate the impact of gibberellic acid on the resistance of two rice cultivars, 'Tarom' and 'Shiroudi' under sodium arsenate stress.

## MATERIAL AND METHODS

### Plant materials and treatments

Seeds of 'Tarom' and 'Shiroudi' rice were prepared from the Center of Rice Research in Amolecity, Mazandaran, Iran. Experiments were conducted in Paddy fieldsin thecityof Sari at the north of Iran, at latitude of 36.33 and longitude53andat height of25.70 metersofsea levelin 2013in 4 replicates. The seeds were sterilized in 10% (v/v) sodium hypochlorite for 10 min and then transferred in wet soilcondition for germination. The 25 days-old seedlings with 2-3leaveswere transplanted inpots (4 in each pot) filled with field soil. Soil chemical and physical properties of the filled were analyzed (Table 1). The 30 days-old seedlings were treated with three concentrations of sodium arsenate (0, 50 and 100 μM) and two concentrations of gibberellic acid (0 and 10 μM). After two weeks of treatment, the seedlings were harvested for analyzing.

### Preparation of plant extracts

For the examinationof solubleprotein and enzymatic antioxidants activities,0.1 goffreshleafand roottissue were grinded separately in liquid nitrogenand 0.1M buffer phosphateof potassium (pH 6.8).The extracts werecentrifuged separately at12,000rpmfor 20 minat 4°C.

### Soluble protein assay

After centrifugation, the above extract was carefully transferred to another microtube. Leaf and root soluble protein content of 'Tarom' and 'Shiroudi' rice were examined using spectrophotometer (UV/Vis) atwavelengthof 595 nm, according to the method of Bradford (1976) with bovine serum albumin as a standard.

### Enzymatic antioxidants activities assay

Peroxidase (POD) activity was measured using Dazy*et al.* (2008) method, Catalase (CAT) activity using Johansson and Borg(1988) method, and Superoxide Dismutase (SOD) activity ofleavesand roots of the two rice cultivars (Tarom and Shiroudi) were examined using the method of Giannopolitis and Ries (1977).

### Growth parameters assay

To measure thefresh weight of the plant shoots and roots, the rootsand shoots were separated and then weighted using an accurate balance. Also,root length, stem lengthand leaf length and leaf width were measured (Evans and Hughes, 1962). Dry weightof the plant shoots and roots were measured after 24 h drying in oven at 70°C.

### Photosynthetic pigments assay

The amounts of photosynthetic pigments were determined using Lichtenthaler (1987) method. Pigmentswereextractedfromleaveswith80%acetone, the extracts filtered with Whatman filter paper, and thenthe pigments were examined using spectrophotometer (UV/ Vis) at wavelengths of 470, 646.8 and 663.2 nm. The

amounts of photosynthetic pigments were quantified using the following formula:

$$\text{Chl.}\,a = (12.25\ \text{A663.2} - 2.79\ \text{A646.8})$$

$$\text{Chl.}\,b = (21.21\ \text{A646.8} - 5.1\ \text{A663.2})$$

$$\text{Chl. T} = \text{Chl.}\,a + \text{Chl.}\,b$$

$$\text{Car.} = (1000\ \text{A470} - 1.8\ \text{Chl.}\,a - 85.02\ \text{Chl.}\,b/198)$$

**Statistical analysis**

A completely randomized design with four replicates was used in each experiment. The means were separated by Duncan's multiple range test (DMRT) using SPSS (version 16.0) and presented as mean ± standard deviation (SD).

**RESULTS AND DISSCUSSION**

**Soluble protein content**

The effect of sodium arsenate ($Na_2HAsO4$) and gibberellic acid ($GA_3$) on soluble protein content of leaves and roots in 'Tarom' and 'Shiroudi' rice compared to control is presented in tables 2 and 3. According to the results, soluble protein content in leaves and roots increased significantly at both sodium arsenate concentrations for the two cultivars. However, the increase in 'Shiroudi' was clearer than 'Tarom' under sodium arsenate treatment. Moreover, soluble protein content of leaves and roots increased significantly at treatments of $GA_3$ and sodium arsenate compared with control in both examined rice cultivars. Environmental stresses such as heavy metals have negative impacts on protein content of plants. The results of the current study showed that sodium arsenate increased soluble protein content of 'Tarom' and 'Shiroudi' rice (Tables 2 and 3). Similar results have been foundin *Zeamays* L. treated with lead (Pb) (Hussain *et al.*, 2013) and in *Nasturtium officinale* exposed to arsenite (Ozturk*et al.*, 2010).

Soluble protein content is an important indicator of physiological status of plants. This increase in protein content induces adaptive responses of plants such as increasing antioxidative activities and proline content. The increase in protein content can be attributed to increasing enzymatic proteins synthesis e.g. antioxidants to confront the negative impacts under stress conditions (Mittal *et al.*, 2012).

According to the results of this study, sodium arsenate along with $GA_3$ treatments significantly increasedsoluble protein content in both examined rice cultivars. Similar results werereported in sugarcane plants exposed to gibberellic acid under Pb, Cu and Cd stress in green algae of *Chlorella vulgaris* (Piotrowska-Niczyporuk*et al.*, 2012) and in *Triticumaestivum*L. under Zn, Pb and Cd stress (Ergün and Öncel, 2012).

**Peroxidase activities**

Sodium arsenate treatment increased peroxidase (POX) activity of leaves and roots of both rice cultivars, and this impact was significant at 100 µM sodium arsenate treatment. Meanwhile, using $GA_3$ along with sodium arsenate significantly increased POX activity of leaves and roots in both examined rice cultivars, and the increase in 'Tarom' leaves of was more than that of 'Shiroudi'(Tables 2 and 3). The POX activity in the roots and leaves of 'Tarom' and 'Shiroudi' rice (Tables 2 and 3) showed that sodium arsenate and gibberellic acid significantly increased POX activity. Increased POX activity under heavy metals stress had been reported by Chaoui*et al.* (1997) in bean *(Phaseolus vulgaris* L.*)* under Cd and Zinc stress and Choudhary*et al.* (2012) in *Raphanussativus* L. under Cr stress.

Increasing POX activity was used as a biomarker of stress that might be due to localization of peroxidase in cell walls because, it contribute in lignin biosynthesis as a physical inhibition against toxic materials (Erdal*et al.*, 2011). Moreover, $GA_3$ increased POX activity in roots and leaves of both rice cultivars and this impact in theleaves was more than roots. These results are in

agreement with the results found in in cherry tomato *(Solanumlycopersicum* L.*)* fruit treated with GA under chilling injury stress (Ding *et al.,* 2015) and in maize treated with $GA_3$ under salinity stress (Tuna *et al.,* 2008).

**Catalase activity**

The effect of sodium arsenate and $GA_3$ on leaf and root catalase activity in 'Tarom' and 'Shiroudi' rice compared to control is presented in tables2 and 3. Sodium arsenate significantly increased CAT activity of leaves and roots of both rice cultivars at 50 and 100 µM concentrations; however, this impact at 100 µM was greater than 50 µM. Also, the treatment of sodium arsenate along with $GA_3$ significantly increased CAT activity of leavesand roots in both rice cultivars. In this study, the increased in CAT activity at both concentrations of sodium arsenate indicating the role of CAT in detoxification of $H_2O_2$ under arsenic stress (Tables 2 and 3). This finding is in an agreement with the results of Wang *et al.* (2012) in *Vallisnerianatans* under Pb stress, and Zhang *et al.* (2007) in *Kandeliacandel* and *Bruguieragymnorrhiza* seedlings treated with $Pb^{2+}$, $Cd^{2+}$, and $Hg^{2+}$.

Catalase is the main antioxidant enzymes that eliminate $H_2O_2$ in the mitochondria and microbodies (Liu *et al.,* 2009). It is an important scavenger of $H_2O_2$produced during photorespiration and stress conditions (Dazy*et al.,* 2009) and convert $H_2O_2$ into $H_2O$ and $O_2$ through two electrons transfer and prevent the generation of $OH^{\bullet}$ and consequently protect proteins, nucleic acids and lipids against ROS (Gallego*et al.,* 1996). The current results showed that $GA_3$ increased CAT activity and improved the resistance of the plants against active oxygen radicals produced under sodium arsenate stress. Similar results had been reported in *Dracocephalummoldavica*L. (Rezaei*et al.,* 2013), *Brassica juncea* (Yusuf *et al.,* 2008) and in green algae of *Chlorella vulgaris* treated with gibberellin under Pb, Cd and Cu stress (Piotrowska-Niczyporuk*et al.,* 2012).

**Superoxide dismutase activity**

According to tables 2 and 3, the activities of leaf superoxide dismutase (SOD) of both cultivars increased significantlyunder sodium arsenate and $GA_3$ treatments, but the impact was not significant in roots of both rice cultivars. The SOD activity of leaves and roots of both cultivars increased significantly at 100 µM sodium arsenate concentration along with $GA_3$ treatment. The results of this study indicated that SOD activity increased with increasing sodium arsenate concentration in roots and leaves of both rice cultivars (Tables 2 and 3). Also, according to the reports, heavy metals (Cd, Co, Pb, Cu, As and Ag) increased SOD activity in *Aeluropuslittoralis* (Rastgoo and Alemzadeh, 2011) as well as in *Lupinusluteus* L. (Jomová and Morovič, 2009). Destructive physiological and anatomical impacts would occur in plants that the capacity of antioxidant processes and detoxification mechanisms are lower than the amount of ROS production (Szőllősi, 2014).

Superoxide dismutase is the first enzyme in ROS detoxifying process that converts $O_2^-$ to $H_2O_2$ in cytosol, chloroplast and mitochondria and plays as a defense mechanism against $OH^{\cdot}$formation (Liu *et al.,* 2009). Increased SOD activity in both concentrations of sodium arsenate in ricecultivars indicates the high production of ROS under heavy metals stress (Levent Tuna *et al.,* 2008). Increased activity of SOD enzyme under sodium arsenate stress treated with GA improved plants resistance against oxidative stress. Similarly, It was found that gibberellin increased the activity of SOD in *Triticumaestivum* L. under Ni treatment (Siddiqui *et al.,* 2011) and in cherry tomato *(Solanumlycopersicum* L.*)* fruit under chilling stress(Ding *et al.*, 2015).

**Growth parameters**

Based on the results of this study, the fresh and dry weight of roots and leaves, stem length, root length and

leaf width decreased significantlyat both sodium arsenate concentrations in both cultivars of rice (Tables 4, 5); and this negative impact at 100 µM was greater than 50 µM. However, the growth parameters significantly increased at 100 µM concentration of sodium arsenate compared with 50 µM when the seedlings treated with gibberellin (Tables 4, 5). High temperatures, salinity, drought and heavy metals have negative effect on fresh weight and dry weight of shoots and roots as well as the metabolism and physiological activities of plants (Mathieu *et al.*, 2014; Hayat Bhatti *et al.*, 2013; Nadeem *et al.*, 2014).

Based on the results of this study, sodium arsenate reduced fresh weight and dry weight of roots and leaves and other growth parameters in of both examined cultivars of rice (Tables 4 and 5). Similar results were observed in *Asteriscusmaritimus*treated with NaCl under water stress (Sánchez-Rodríguez*et al.*, 2012). The balance between generation and degradation of ROS were required to protect metabolic functions under these stress conditions to avoid the oxidative injuries. Plants utilize most of their resources under stress conditions to improve their defense mechanisms for growth and development (Howladar, 2014). Also, heavy metals can reduce cell division and growth of stems, roots and in this situation, gibberellin can have a positive impact on plant growth and development (Levent Tuna *et al.*, 2008; Bartoli*et al.*, 2013). The current results were in agreement with those of Shaddad*et al.* (2011) in maize treated with gibberellin under drought stress, Khan*et al.* (2011) in *Aspergillusfumigatus*sp. treated with gibberellin under salinity stress and Ratushnyak*et al.* (2012) in *Pisumsativum*treated with salicylic acid under Pd stress.

**Photosyntheticpigments**

According to table 3, in both cultivars of rice, the content of chlorophylls a and b, total chlorophyll and carotenoids of leaves decreased in both sodium arsenate concentrations, and this impact at 100 µM was greater than 50 µM; however, this decline was not significant for chlorophyll b. Sodium arsenate along with $GA_3$ treatment increased significantlythe amount of chlorophyll a and b, total chlorophyll and carotenoids in both examined rice cultivars. Reduction of the number of chloroplasts, destruction of photosynthetic pigment and reduction of pigment synthesis would occur under stress conditions. Heavy metal stress destroys the structure of chloroplast, grana, thylakoid and also imbalance the pigment protein complex (Miteva*et al.*, 2005). Arsenic has negative impact on photosynthetic pigments of the plants (Azizur-Rahman *et al.*, 2007). In this study, sodium arsenate reduced leaf photosynthetic pigment in both cultivars of rice (Table 6). Similar effect had been reported in *Glauciumflavum* Crantz treated with Cu (Cambrollé*et al.*, 2011), in rice (*Oryza sativa* L.) treated with arsenic (Azizur Rahman *et al.*, 2007), and in barley treated with Cd (Vassilev*et al.*, 2004).

Siddiqui *et al.* (2011) found that gibberellin increased the number of chloroplasts in wheat plants under Ni stress. Phytohormones increase antioxidant activity under heavy metal stress and reduce ROS levels and increase the resistance against heavy metals (Piotrowska-Niczyporuk*et al.*, 2012). The current results regarding the positive impacts of gibberellin on photosynthetic pigments in both cultivars of rice under sodium arsenate treatment are in agreement with the results of Piotrowska-Niczyporuk*et al.* (2012) in *Chlorella vulgaris* treated with gibberellin under Pb and Cu stress and Anuradha and Seeta-Ram-Rao (2003) in rice seeds (*Oryza sativa* L.) treated with brassinosteroids and salt stress.

**CONCLUSION**

According to the results, sodium arsenate treatment increased the antioxidant activities (CAT, POX and

SOD) and soluble protein content. Growth parameters and photosynthetic pigments (chl*a* and*b*, total chlorophyll and carotenoids) reduced in 'Tarom' and 'Shiroudi' rice. $GA_3$ treatment increased soluble protein content, antioxidant activities, growth parameters and photosynthetic pigments and enhanced the resistance of rice under sodium arsenate stress. Furthermore, this study showed that $GA_3$ increased the resistance of the two examined rice cultivars treated with sodium arsenate.

**Acknowledgments**

The authors would like to thank the National Rice Research Center of Amolecity, Mazandaran, Iran for the kind material supports.

**Table 1. Chemical and physicalproperties ofthe soil used in the experiment. CCE (Calcium Carbonate Equivalent), EC (Electric conductance).**

| Depth (Cm) | 0-30 | CCE (%) | 30 |
|---|---|---|---|
| Texture | Clay | Organic carbon (%) | 2 |
| Clay (%) | 36 | Organic matter (%) | 3.44 |
| Silt (%) | 28 | Total nitrogen (%) | 0.15 |
| Sand (%) | 36 | Phosphorus (p.p.m) | 26.7 |
| EC | 1.43 | Potassium (p.p.m) | 294 |
| pH | 7.26 | Arsenic (p.p.m) | <10 |

**Table 2. Effect of gibberellic acid and sodium arsenate on soluble protein contents, peroxidase, catalase and superoxide dismutase activities in leaves of two rice cultivars.**

| Cultivar | Sodium arsenate (µM) | $GA_3$ (µM) | Soluble proteins (mg $g^{-1}$ F.W.) | POX ($\Delta OD g^{-1}$ F.W $min^{-1}$) | CAT ($\Delta OD g^{-1}$ F.W $min^{-1}$) | SOD (U $mg^{-1}$ protein) |
|---|---|---|---|---|---|---|
| Tarom | 0 | 0 | $505.4\pm33^{f}$ | $21.91\pm0.51^{fg}$ | $34.56\pm3.26^{fg}$ | $228.7\pm10.0^{e}$ |
| | | 10 | $1328\pm174^{e}$ | $26.75\pm1.77^{ef}$ | $50.78\pm1.29^{de}$ | $337.8\pm15.3^{d}$ |
| | 50 | 0 | $780.9\pm81.7^{f}$ | $29.83\pm2.16^{de}$ | $62.1\pm2.76^{cd}$ | $791.3\pm8.856^{a}$ |
| | | 10 | $1504\pm165^{cde}$ | $37.917\pm1.91^{bc}$ | $66.48\pm3.80^{c}$ | $772.8\pm20.5^{a}$ |
| | 100 | 0 | $1452\pm90.8^{cde}$ | $41\pm2.54^{ab}$ | $80.24\pm6.32^{ab}$ | $584.6\pm61.5^{b}$ |
| | | 10 | $1877\pm106^{abc}$ | $45.52\pm2.19^{a}$ | $91.08\pm1.86^{a}$ | $777.5\pm29.2^{a}$ |
| Shiroudi | 0 | 0 | $1424\pm131^{de}$ | $3.3\pm0.17^{d}$ | $26.25\pm2.66^{g}$ | $497.7\pm9.65^{bc}$ |
| | | 10 | $1565\pm175^{bcde}$ | $4.05\pm0.15^{d}$ | $41.08\pm5.46^{ef}$ | $522.7\pm32.8^{bc}$ |
| | 50 | 0 | $2260\pm178^{a}$ | $4.35\pm0.15^{d}$ | $36.12\pm2.53^{fg}$ | $487.3\pm17.6^{c}$ |
| | | 10 | $1818\pm146^{bcd}$ | $6.15\pm0.56^{c}$ | $43.77\pm4.55^{ef}$ | $728.3\pm40.6^{a}$ |
| | 100 | 0 | $1498\pm144^{cde}$ | $6.9\pm0.79^{bc}$ | $47.00\pm4.03^{ef}$ | $762.5\pm34.8^{a}$ |
| | | 10 | $1950\pm86.9^{ab}$ | $7\pm0.14^{bc}$ | $69.23\pm7.69^{bc}$ | $735.8\pm13.7^{a}$ |

**Table 3. Effect of gibberellic acid and sodium arsenate on protein contents, peroxidase, catalase and superoxide dismutase activities in roots of two rice cultivars.**

| Cultivar | Sodium arsenate (µM) | $GA_3$ (µM) | Protein (mg $g^{-1}$ F.W.) | POX ($\Delta OD^{-1}$ F.W $min^{-1}$) | CAT ($\Delta ODg^{-1}$ F.W $min^{-1}$) | SOD (U $mg^{-1}$ protein) |
|---|---|---|---|---|---|---|
| Tarom | 0 | 0 | 308.6±46.7$^{ef}$ | 3.3±0.3$^{d}$ | 28.68±1.36$^{ef}$ | 1527±131$^{d}$ |
| | | 10 | 332.5±24.8$^{ef}$ | 4.2±0.24$^{d}$ | 35.32±2.31$^{e}$ | 3765±226$^{c}$ |
| | 50 | 0 | 388.6±36.8$^{e}$ | 4.05±0.37$^{d}$ | 47.71±4.61$^{cd}$ | 1876±67.4$^{d}$ |
| | | 10 | 549.7±45.7$^{d}$ | 7.65±0.61$^{b}$ | 62.4±1.28$^{ab}$ | 2067±67.4$^{d}$ |
| | 100 | 0 | 214.7±23.9$^{fg}$ | 6.9±0.38$^{bc}$ | 54.97±2.97$^{bc}$ | 3547±170$^{c}$ |
| | | 10 | 546.1±45.7$^{d}$ | 10.4±0.37$^{a}$ | 49.04±2.97$^{cd}$ | 2067±162$^{d}$ |
| Shiroudi | 0 | 0 | 90.47±10.3$^{g}$ | 3.3±0.17$^{d}$ | 24.55±2.592$^{f}$ | 6280±353$^{b}$ |
| | | 10 | 724±54.7$^{c}$ | 4.05±0.15$^{d}$ | 45.325±4.038$^{d}$ | 7592±536$^{a}$ |
| | 50 | 0 | 601.2±60.6$^{cd}$ | 4.35±0.15$^{d}$ | 31.567±2.375$^{ef}$ | 7605±593$^{a}$ |
| | | 10 | 1177±42.7$^{b}$ | 6.15± 0.56$^{c}$ | 58.3±2.875$^{ab}$ | 5893±285$^{b}$ |
| | 100 | 0 | 221.1±53$^{fg}$ | 6.9±0.79$^{bc}$ | 43.625±3.064$^{d}$ | 6398±449$^{b}$ |
| | | 10 | 1529±48.9$^{a}$ | 7±0.14$^{bc}$ | 64.3±2.002$^{a}$ | 6341±449$^{b}$ |

**Table 4. Effect of gibberellic acid and sodium arsenate on fresh and dry weight of shoots and roots of two rice cultivars.**

| Cultivar | Sodium arsenate (µM) | $GA_3$ (µM) | Fresh weight shoots(g/plant) | Fresh weight (g/plant)roots | Dry weight shoots (g/plant) | Dry weight roots (g/plant) |
|---|---|---|---|---|---|---|
| Tarom | 0 | 0 | 4.64±0.24$^{a}$ | 1.569±0.19$^{a}$ | 0.746±0.05$^{bc}$ | 0.178±0.01$^{b}$ |
| | | 10 | 4.807±0.10$^{a}$ | 1.607±0.13$^{a}$ | 0.886±0.05$^{a}$ | 0.226±0.01$^{a}$ |
| | 50 | 0 | 4.362±0.22$^{a}$ | 1.203±0.07$^{b}$ | 0.581±0.02$^{d}$ | 0.146±0.008$^{c}$ |
| | | 10 | 4.562±0.15$^{a}$ | 1.391±0.05$^{ab}$ | 0.805±0.05$^{ab}$ | 0.197±0.007$^{ab}$ |
| | 100 | 0 | 1.91±0.20$^{e}$ | 0.489±0.06$^{d}$ | 0.450±0.04$^{e}$ | 0.056±0.007$^{gh}$ |
| | | 10 | 3.85±0.16$^{b}$ | 1.24±0.03$^{b}$ | 0.670±0.03$^{cd}$ | 0.131±0.019$^{cd}$ |
| Shiroudi | 0 | 0 | 2.435±0.26$^{d}$ | 0.685±0.07$^{cd}$ | 0.396±0.02$^{ef}$ | 0.083±0.009$^{efg}$ |
| | | 10 | 2.918±0.20$^{c}$ | 0.860±0.06$^{c}$ | 0.615±0.02$^{d}$ | 0.107±0.004$^{de}$ |
| | 50 | 0 | 1.262±0.03$^{fg}$ | 0.609±0.04$^{c}$ | 0.306±0.02$^{fg}$ | 0.061±0.006$^{fgh}$ |
| | | 10 | 1.6±0.17$^{fg}$ | 0.741±0.05$^{cd}$ | 0.441±0.03$^{e}$ | 0.096±0.008$^{e}$ |
| | 100 | 0 | 0.828±0.06$^{g}$ | 0.241±0.02$^{e}$ | 0.249±0.04$^{g}$ | 0.037±0.005$^{h}$ |
| | | 10 | 1.651±0.05$^{ef}$ | 0.546±0.03$^{d}$ | 0.331±0.02$^{efg}$ | 0.092±0.004$^{ef}$ |

**Table 5. Effect of gibberellic acid and sodium arsenate on stem length, leaf length, leaf width and root length of two rice cultivars.**

| Cultivar | Sodium arsenate (µM) | $GA_3$ (µM) | Stem length(cm) | Leaf length (cm) | Leaf width(mm) | Root length (cm) |
|---|---|---|---|---|---|---|
| Tarom | 0 | 0 | 29±2.79$^{ab}$ | 41±20.04$^{b}$ | 10.5±0.95$^{a}$ | 13.375±1.51$^{f}$ |
| | | 10 | 32±1.22$^{a}$ | 54.75±2.75$^{a}$ | 10.75±0.47$^{a}$ | 25.75±1.65$^{ab}$ |
| | 50 | 0 | 24.5±1.70$^{c}$ | 40±1.87$^{bc}$ | 7.75±0.47$^{cd}$ | 20.75±1.03$^{cd}$ |
| | | 10 | 31.5±0.64$^{a}$ | 58±2.34$^{ab}$ | 9.75±0.47$^{ab}$ | 21±1.87$^{cd}$ |
| | 100 | 0 | 23.75±1.18$^{cd}$ | 34.75±1.10$^{cd}$ | 6±0.40$^{def}$ | 15.25±1.10$^{ef}$ |
| | | 10 | 30±0.70$^{a}$ | 45±2.73$^{b}$ | 8.75±0.47$^{bc}$ | 29.5±0.64$^{a}$ |
| Shiroudi | 0 | 0 | 22.75±0.85$^{cd}$ | 40.75±1.49$^{b}$ | 6.75±0.47$^{de}$ | 24.75±1.43$^{bc}$ |
| | | 10 | 25.75±0.85$^{bc}$ | 44.5±1.19$^{b}$ | 7.5±0.64$^{cde}$ | 27.5±1.19$^{ab}$ |
| | 50 | 0 | 20.25±0.98$^{de}$ | 34.5±2.32$^{bc}$ | 5.75±0.47$^{ef}$ | 18.5±1.19$^{de}$ |
| | | 10 | 22.75±0.74$^{cd}$ | 41.25±1.31$^{b}$ | 7.75±0.47$^{cd}$ | 26±0.81$^{ab}$ |
| | 100 | 0 | 18.25±0.47$^{e}$ | 30±1.08$^{d}$ | 5±0.57$^{f}$ | 17±1.82$^{def}$ |
| | | 10 | 23.5±0.64$^{cd}$ | 40.25±0.47$^{bc}$ | 7.25±0.47$^{cde}$ | 25.25±1.18$^{ab}$ |

**Table 6. Effect of gibberellic acid and sodium arsenate on photosyntheticpigments of two rice cultivars.**

| Cultivar | Sodium arsenate (µM) | $GA_3$ (µM) | Chlorophyll *a* (mg $g^{-1}$ F.W) | Chlorophyll *b* (mg $g^{-1}$ F.W) | Totalchl. (mg $g^{-1}$ F.W) | Carotenoids (mg $g^{-1}$ F.W) |
|---|---|---|---|---|---|---|
| Tarom | 0 | 0 | 1.808±0.10$^{cd}$ | 0.793±0.04$^{cde}$ | 2.601±0.14$^{cd}$ | 0.438±0.01$^{cde}$ |
| | | 10 | 2.709±0.18$^{a}$ | 1.263±0.08$^{a}$ | 3.972±0.27$^{a}$ | 0.575±0.05$^{a}$ |
| | 50 | 0 | 1.632±0.06$^{cd}$ | 0.722±0.02$^{e}$ | 2.355±0.08$^{cde}$ | 0.382±0.01$^{ef}$ |
| | | 10 | 2.227±0.07$^{b}$ | 0.973±0.03$^{cd}$ | 3.201±0.11$^{b}$ | 0.544±0.01$^{ab}$ |
| | 100 | 0 | 1.479±0.007$^{de}$ | 0.668±0.005$^{e}$ | 2.148±0.004$^{de}$ | 0.353±0.006$^{f}$ |
| | | 10 | 1.878±0.01$^{c}$ | 0.769±0.009$^{de}$ | 2.648±0.01$^{cd}$ | 0.460±0.01$^{bcde}$ |
| Shiroudi | 0 | 0 | 1.869±0.12$^{c}$ | 0.864±0.07$^{cde}$ | 2.736±0.20$^{bc}$ | 0.472±0.02$^{bcd}$ |
| | | 10 | 2.594±0.07$^{a}$ | 1.175±0.06$^{ab}$ | 3.776±0.14$^{a}$ | 0.538±0.001$^{ab}$ |
| | 50 | 0 | 1.827±0.21$^{c}$ | 0.81±0.11$^{cde}$ | 2.639±0.32$^{cd}$ | 0.411±0.05$^{def}$ |
| | | 10 | 2.218±0.06$^{b}$ | 1.00±0.019$^{bc}$ | 3.226±0.08$^{b}$ | 0.523±0.001$^{abc}$ |
| | 100 | 0 | 1.189±0.05$^{e}$ | 0.689±0.006$^{e}$ | 1.875±0.06$^{e}$ | 0.111±0.005$^{g}$ |
| | | 10 | 1.859±0.13$^{c}$ | 0.747±0.12$^{e}$ | 2.674±0.20$^{cd}$ | 0.421±0.03$^{def}$ |

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# تأثير استخدام زرنيخ الصوديوم وحمض الجبريليك على النمو ونشاط الانزيمات المانعة للأكسدة وصبغات التمثيل الضوئي في صنفين من الأرز

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## ملخص

تم اجراء هذه التجربة لدراسة تأثيراستخدام حمض الجبريليك وزرنيخ الصوديوم على نشاط الانزيمات المانعة للأكسدة ومحتوى البروتين الذائب والنمو وصبغات التمثيل الضوئي (كلوروفيل "أ" وكلوروفيل "ب"، والكلوروفيل الكلي والكاروتينويدات) في صنفي الأرز "تاروم" و"شيرودي". تم معاملة البادرات بتراكيز محتلفة من زرنيخ الصوديوم (صفر، 50 و 100 ملي مولر) وحمض الجبريليك (صفر و100 ملي مولر) لمدة اسبوعين. بينت النتائج ان المعاملة بزرنيخ الصوديوم زادت معنويا نشاط الانزيمات المانعة للأكسدة ومحتوى البروتين بينما خفضت النمو ومحتوى صبغات التمثيل الضوئي (كلوروفيل"أ" وكلوروفيل "ب"والكاروتينويدات) في كلا الصنفين. كما أظهرت النتائج ان حمض الجبريليك زاد معنويا نشاط الانزيمات المانعة للأكسدة ومحتوى البروتين والنمو وصبغات التمثيل الضوئي (كلوروفيل "أ" وكلوروفيل "ب"والكاروتينويدات) في النباتات المعاملة بزرنيخ الصوديوم في صنفي الأرز. يظهر من النتائج أن المعاملة بحمض الجبريليك زادت مقاومة النباتات المعاملة بزرنيخ الصوديوم في كلا الصنفين.

**الكلمات الدالة:** الأرز، زرنيخ الصوديوم، حمض الجبريليك، نشاط الانزيمات المانعة للأكسدة، صبغات التمثيل الضوئي، البروتين الذائب.

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تاريخ استلام البحث 2016/4/3 وتاريخ قبوله 2016/7/11.